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AXIS-CROSSING GENERATOR (ACG),(U)
SEP 67 L R WEILL, J A NESHEIM
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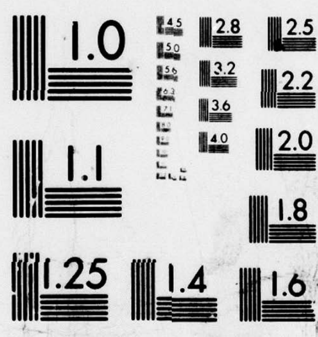
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AXIS-CROSSING GENERATOR (ACG),

10 ~~by~~ L.R./Weill ~~and~~ J. A/ Nesheim

San Diego, California

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FOREWORD

This technical note describes the characteristics, operation and application of an electronic device called the Axis-Crossing Generator (ACG).

This memorandum has been prepared in the interest of others at NUWC and possibly a few persons or activities outside NUWC. It presents, for information, a small portion of the work being done in the area of sonar signal measurement and analysis.

CONTENTS

FIGURES

TABLES

BACKGROUND

Code D506 is investigating the usefulness of phase and amplitude characteristics of sonar signals, as measured on a cycle-by-cycle basis, for target detection and classification.

A Digital Axis-Crossing Interval Measurement System (DACIM) is being developed to measure zero axis crossing intervals and positive peak amplitude of signals between 0 and 25 KCPS. The digitized interval and amplitude information will be recorded on magnetic tape for subsequent analysis.

To check the performance of DACIM, it is necessary to have available, some representative sonar signals which have very accurately known axis crossing times. These signals are obtained by generating an axis-crossing ramp of predetermined slope from a fast risetime step. This memorandum describes a device which generates such a ramp.

INTRODUCTION to the AXIS-CROSSING GENERATOR (ACG)

The Axis Crossing Generator (see ACG Block Diagram Fig. 1), produces an output voltage which periodically passes from negative to positive values. Such a polarity shift we will call a positive-going axis crossing (PGAC). By means of a selector switch, negative-going axis crossings (NGAC) may also be produced. However, in the discussion which follows, we will consider only the PGAC, it being understood that what we say also applied to NGAC's.

The PGAC (Fig. 2) is a voltage ramp (actually the initial part of an RC charge waveform) which starts at -2 millivolts and rises through zero to a positive value. The ramp is generated by passing a voltage step through a simple RC integrator located in the RAMP GENERATOR chassis. The voltage step has a very fast risetime (on the order of 0.2 nanosecond), so that the time at which the step occurs is known precisely. This instant of time serves as a reference (t = 0) for the timing of events which follow. The time at which the ramp passes through zero (relative to the reference time t = 0), is known very accurately because the starting voltage of the ramp is small (-2 mv.) and the ramp slope is sufficiently steep to make component value deviations in the RC integrator insignificant. Note that only the timing of the PGAC relative to t = 0 is important. The time at which the PGAC occurs relative to some other time frame is unimportant. Knowing that the axis crossing occurs d nanoseconds after the step transition, we may then apply the ramp to the DACIM axis-crossing detector and note that the output of the detector occurs Y nanoseconds after the step transition. The quantity (Y - d) is the error of the axis-crossing detector (see Fig. 4, ACD error).

In addition to the basic function of generating PGAC's, the ACG has one refinement. Immediately prior to each PGAC, a negative half cycle of a

sine wave may be applied so that the axis crossing "appears" to be that of a sine wave. The period of the sine wave is the same as the interval between successive PGAC's. The amplitude of the wave form may be varied. The sine wave is applied to saturate the axis-crossing detector input transistors, thus testing for "memory effect" errors caused by stored base charge in these transistors. A sine wave was selected rather than a square wave because a sine wave is more representative of signals which would actually be encountered in using DACIM.

FUNCTIONS of MAJOR COMPONENTS

The major components of the ACG (see ACG Block Diagram, Fig. 1) are:

(1) The Time Base Generator (TBG)

(2) The Ramp Trigger Pulse Generator (RTPG)

(3) The Fast-Rise Pulse Generator (FRPG)

(4) The Post-Ramp Offset Pulse Generator (PROPG)

(5) The Ramp Generator (RG)

(1) <u>Time Base Generator</u> (TBG): The time base generator is an oscillator/square wave generator which clocks the entire sequence of events in the ACG. The period between successive PGAC's is controlled by this unit, and in addition, it provides the negative half cycle of the sine wave which precedes each PGAC. The TBG is a Wavetek model 105 signal generator.

(2) <u>Ramp Trigger Pulse Generator</u> (RTPG): The RTPG, which is triggered by the TBG, provides a delayed pulse output which serves as a trigger for the Post-Ramp Offset Pulse Generator and the Fast-Rise Time Pulse Generator. The delayed output is required in order to obtain the proper time relationship between the pre-ramp sine wave and the ramp itself. The RTPG is an

Intercontinental Instrument Incorporated model PG-2 variable rise-time pulse generator.

(3) Fast-Risetime Pulse Generator (FRPG): The FRPG is triggered by the RTPG to produce an extremely fast-risetime pulse (risetime is 0.2 nanosecond). The output of the FRPG is used to trigger the Ramp Generator and to act as a time reference (t = 0) for the measurement of the time at which a PGAC occurs. The FRPG is a Hewlett Packard model 213B pulse generator.

(4) Post-Ramp Offset Pulse Generator (PROPG): The PROPG, triggered by the RTPG, assures that the output of the ramp generator remains positive following each PGAC. The PROPG is a Rutherford model 15B pulse generator.

(5) The Ramp Generator (RG): The RG, when triggered by the FRPG, generates a ramp (the initial part of an RC charge curve). The slope of the ramp depends upon the RC time constant used. There are four different time constants available, each generated within its own separate RG chassis. The different time constants are for use at repetition frequencies of 25 cps, 250 cps, 2.5 kc, and 25 kc. The respective delays between the fast risetime step and the axis crossings for these four frequencies are 1530 ns, 153 ns, 15.3 ns, and 1.53 ns. The voltage level at which the ramp starts (-2 mv) is determined by an adjustable power supply, shown in the Block Diagram. The power supply is a Hewlett Packard model 721 A power supply.

Figures 2 and 3 show the input/output waveforms for the major components of the ACG, when operating in the PGAC and NGAC modes of operation.

THEORY of OPERATION, RAMP GENERATOR

The Ramp Generator is the component from which the output of the ACG is taken. It forms its output by combining the signals from the FRPG, power supply, PROPG, and TBG. These signals are shown in proper time sequences for a PGAC in Figure 2. A schematic is shown in Figure 5.

Initially, the output signal is positive because of the positive signal from the PROPG. When the sine wave output of the TBG becomes negative relative to the output, the bias on the 1N914 diode changes from reverse to forward. This change effectively connects the output to the TBG so that the output signal is the same as the TBG signal. Through the voltage divider formed by R2, R3, and R4, the power supply adds a constant component of -2 mv. to the signals that form the output. As soon as the TBG signal becomes greater than this component voltage, the bias on the 1N914 becomes reversed again. This change causes the output to stay at -2 mv. Then the fast risetime pulse is initiated, which causes capacitor C1 to charge through R1. The exponentially rising voltage across C1 causes the output voltage to rise from -2 mv. through zero, thus generating an axis-crossing. At the conclusion of the FRPG pulse, the output voltage would decay back to -2 mv. if it were not for the positive signal from the PROPG. The end of the FRPG pulse and its subsequent decay concludes an ACG cycle.

Diodes CR3 and CR4 form a clamp that keeps C1 from being charged to an excessively high voltage when the sine wave is added to the ACG output. The PROPG input diodes form a gate that will not conduct until the PROPG signal has reached the diode threshold voltage. The PROPG signal is shown in Figure 2 to be zero on alternate half-cycles. Actually, the output circuitry of the PROPG causes the signal to be offset from zero by a small amount. Diodes CR1 and CR2 keep this residual voltage from interfering with the output of the RG respectively, for a PGAC and a NGAC. Each diode blocks the residual voltage because it cannot conduct until it is biased sufficiently in the forward direction to exceed its conducting threshold.

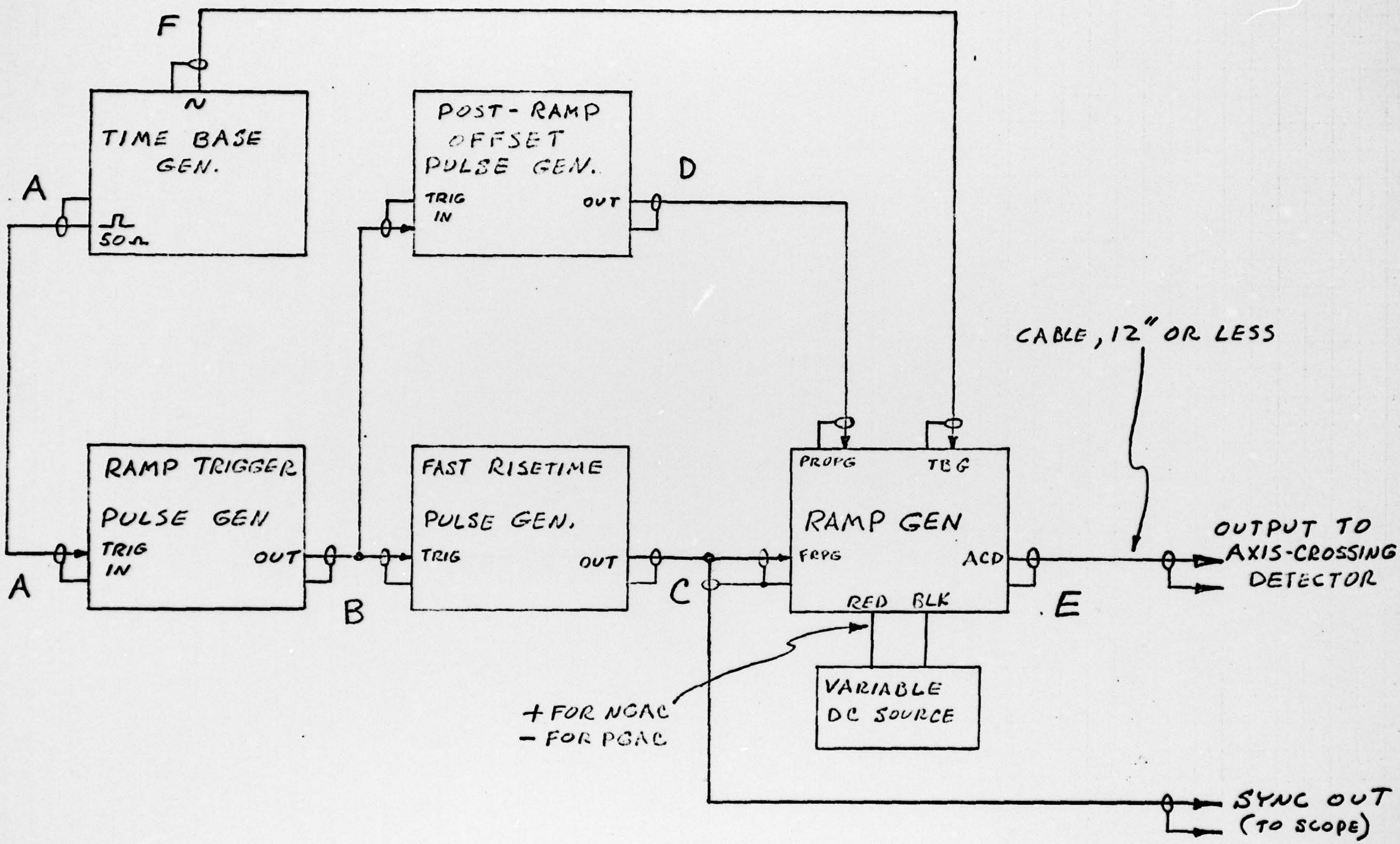


FIG. 1 ACG BLOCK DIAGRAM

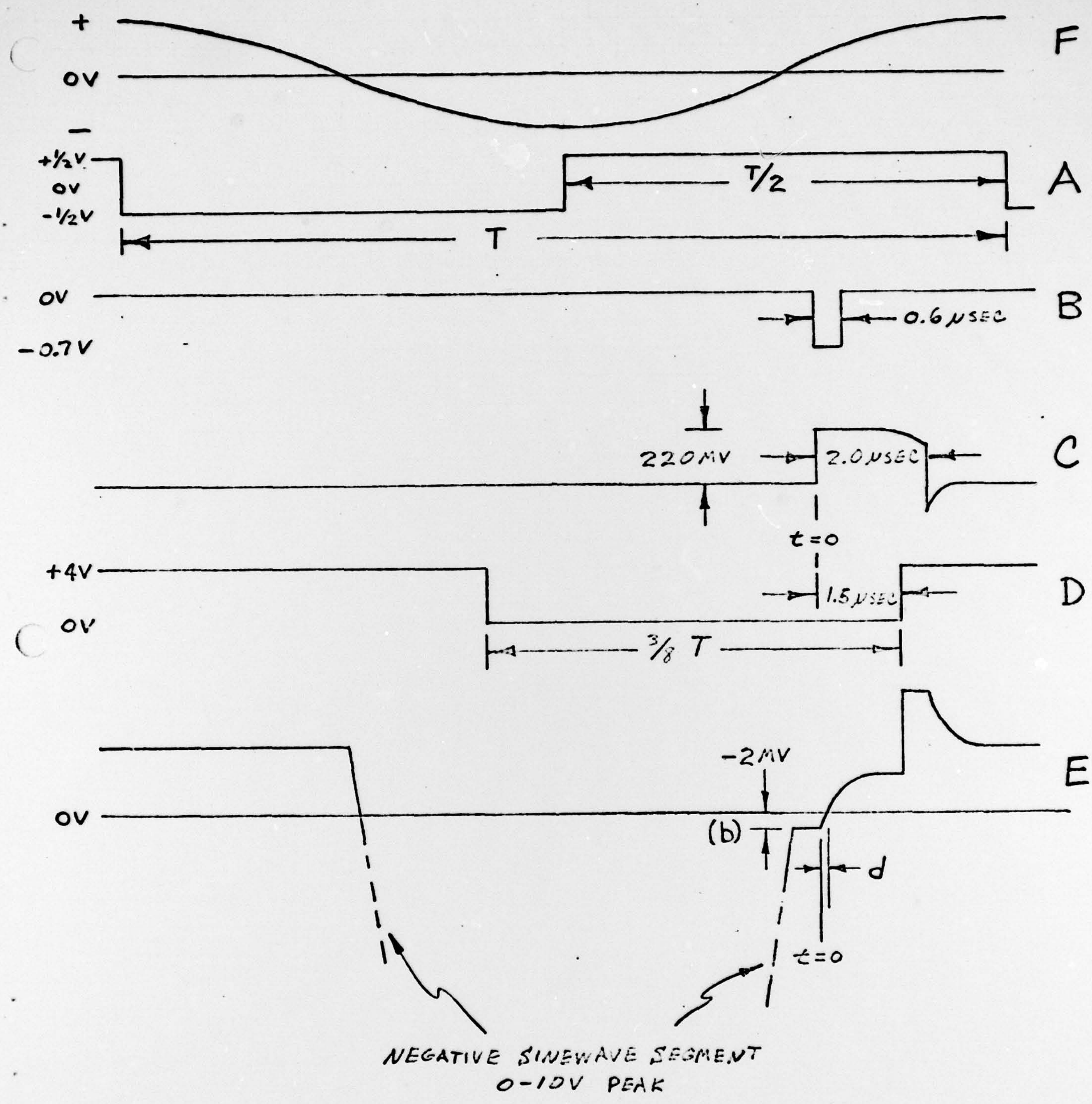


FIG. 2 WAVEFORMS FOR PGAC

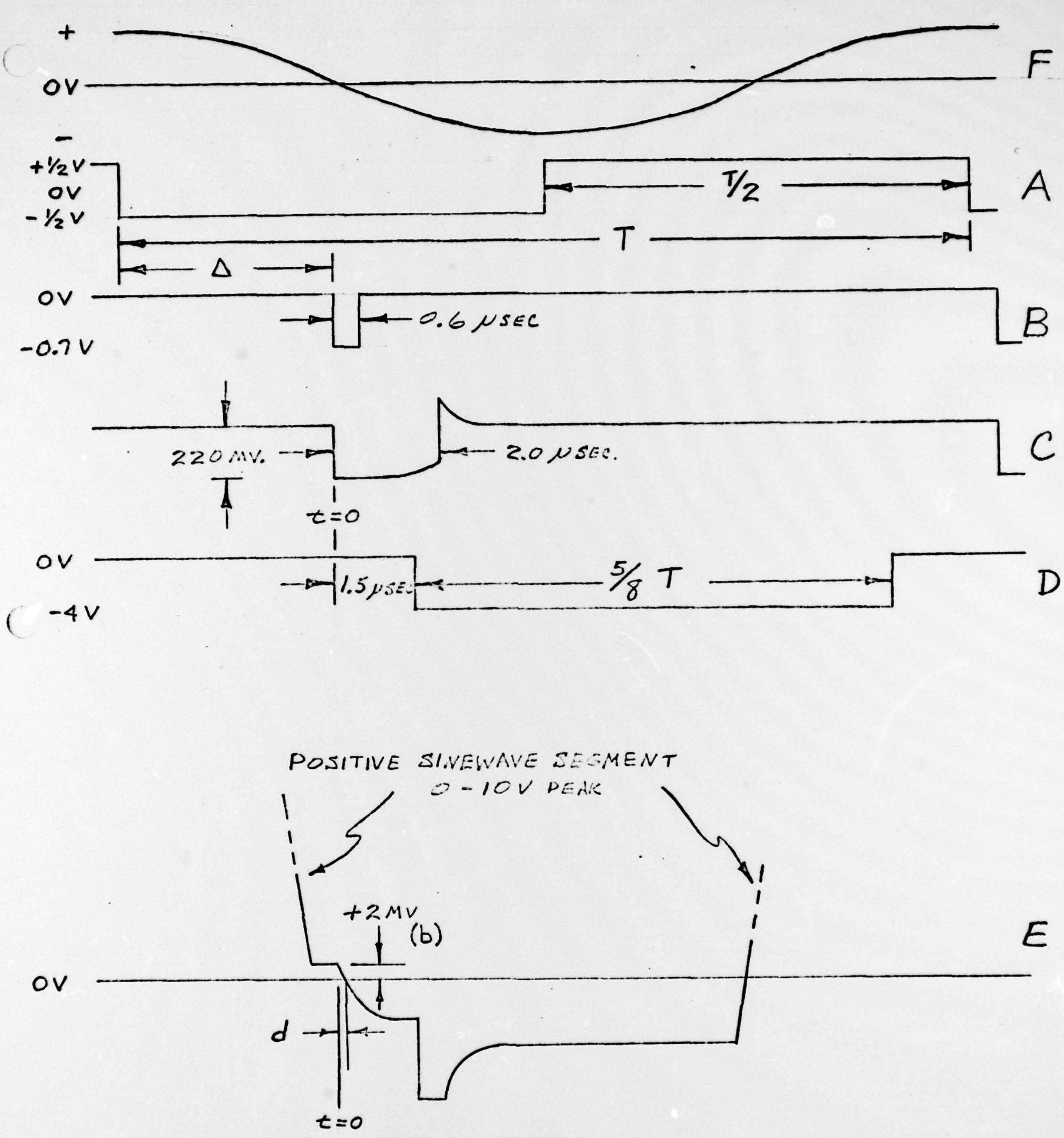
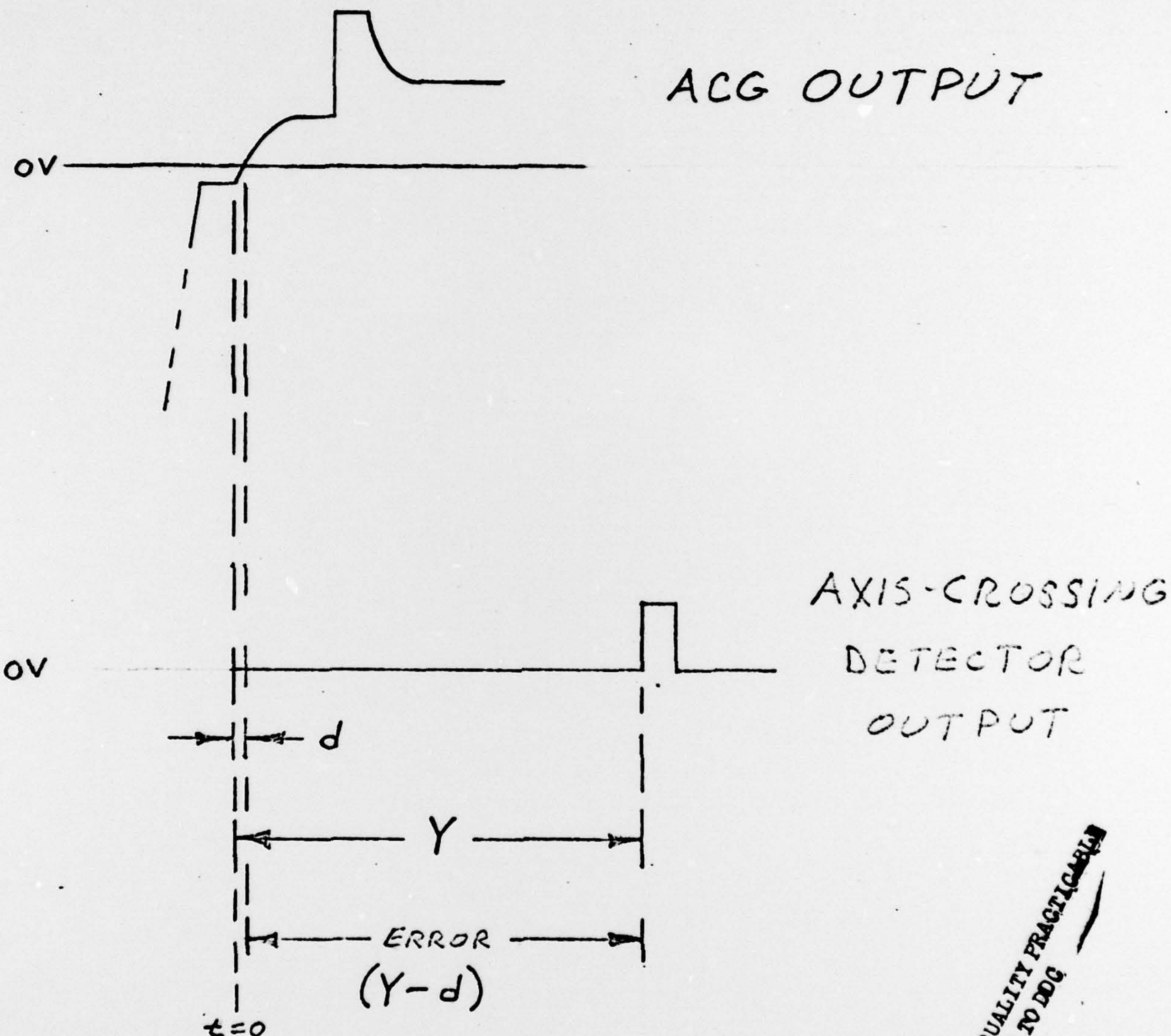


FIG. 3 WAVEFORMS FOR NGAC



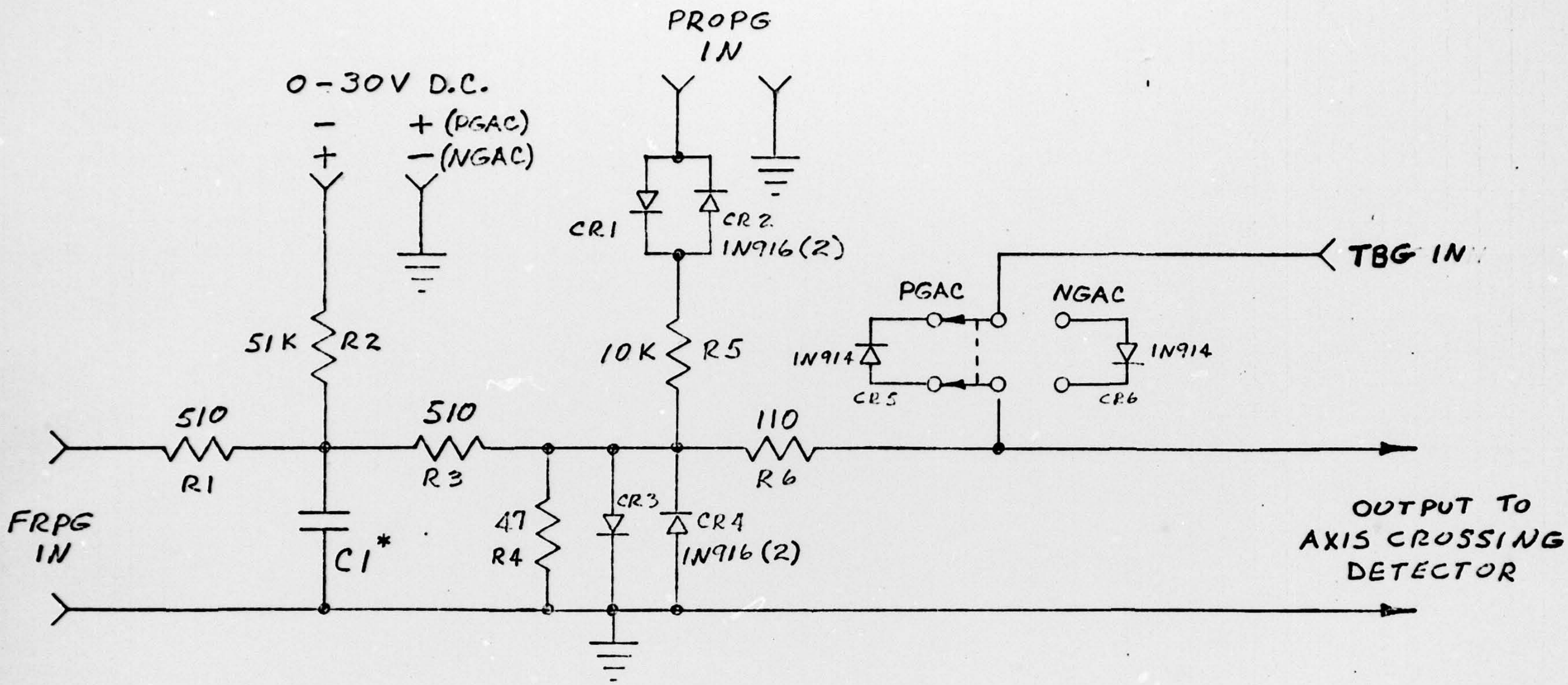
d = 1.53 m SEC. , 25 KC

= 15.3 m SEC. , 2.5 KC

= 153 m SEC. , 250 CPS

= 1530 m SEC. , 25 CPS

FIG. 4 AXIS-CROSSING DETECTOR ERROR



Ramp Gen. #	Equivalent Sine Wave Freq.	C*
1	25 cps	33,000 pf
2	250 "	3,000 "
3	2500 "	300 "
4	25000 "	30 "

Note: Slight differences in resistor values may be noticed from unit to unit.

FIG. 5 RAMP GENERATOR SCHEMATIC

OPERATOR'S SECTION

PREPARATION for USE

First determine which of the 4 equivalent sine wave frequencies is to be used for a particular test; 25 kc, 2.5 kc, 250 cps, 25 cps. This will, in turn, determine which one of the four Ramp Generators to incorporate into the ACG.

Connect all major components of the ACG as per Figure 1 ACG Block Diagram, using coaxial cable everywhere except for the Variable DC Source connection, which can be "hook-up" wire. The cable connecting the Ramp Generator and Axis-Crossing Detector should be short as possible and not to exceed 12 inches in length.

Next, refer to the Adjustments Table which applies to the chosen equivalent sine wave frequency. Working from left to right across the table, make adjustments indicated in row 2, then row 3 and so on, using an oscilloscope when called for. Note that the upper half of each table applies to NGAC's and the lower half to PGAC's.

OPERATING PROCEDURE

After the ACG has been readied for use, connect it, using coaxial cable, to the Axis-Crossing Detector and Sampling Oscilloscope as shown in Figure 6.

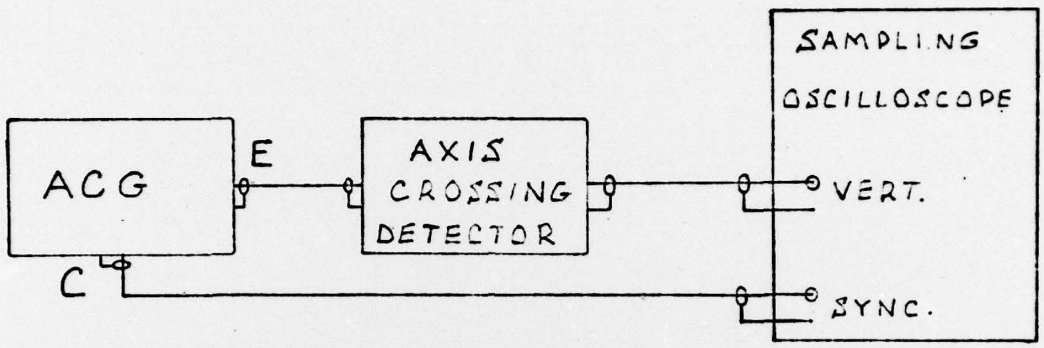


FIGURE 6 OPERATIONAL CONNECTIONS DIAGRAM

Observe the scope trace and measure the time Y from the beginning of the sweep to the leading edge of the Axis-Crossing Detector output pulse. This time represents the sum of the fixed time delay "d" inherent in the RG (different for each equivalent sine wave frequency) and the Axis-Crossing Detector error. Subtracting "d" from the quantity Y displayed on the scope yields the Axis-Crossing Detector error.

NCAC + Output of Variable-V source goes to red binding post

	OPERATING MODE SW.	TRIGGER SLOPE SW.	THRESHOLD * SENSITIVITY	SLOPE * SENSITIVITY	FREQUENCY *	PULSE DELAY (Δ)	PULSE * WIDTH	OFFSET SWITCH	DP/DELAY SWITCH	NORMAL/COMP SWITCH "	RISETIME CONTROL	FALLTIME CONTROL	POLARITY SWITCH	AMPLITUDE * ADJUST
B: RAMP TRIGGER PULSE GENERATOR	EXT/ MANUAL	- (Negative)	Adjust for stable triggering	Maximum Negative	Not Applicable	11μ sec.	0.6μ sec.	OFF	DELAY	NORMAL	Minimum (10ns)	Minimum (10ns)	- (NEGATIVE)	-0.7 volts PEAK
D: POST-RAMP/OFFSET PULSE/ GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	1.5μ sec.	25μ sec	OFF	DELAY	NORMAL	Minimum (10ns)	Minimum (10ns)	- (NEGATIVE	-4.0 volts

	TRIGGER POLARITY SW.	TRIGGER * SENSITIVITY	OUTPUT POLARITY SW.	STEP INPUT * MAGNITUDE	PRE-RAMP * OFFSET(b) ADJ	AXIS-CROSSING DIRECTION SW	DIAL MULTIPLIER	Freq. CPS * (PERIOD)	WAVEFORM	OUTPUT * AMPLITUDE	VCG	50 Ω OUTPUT AMPLITUDE
C: FAST-RISE PULSE GENERATOR	NEG.	As required to get a stable output	NEG.									
E: RAMP GENERATOR				220 mv.	+2.0 mv.	NCAC						
A-F: TIME BASE GENERATOR							X10K	25Kc ($T = 40\mu$ sec)		Adjust for desired test conditions	Minimum	Maximum

PCAC + Output of Variable-V Source goes to black binding post.

	OPERATING MODE SW.	TRIGGER SLOPE SW.	THRESHOLD * SENSITIVITY	SLOPE * SENSITIVITY	FREQUENCY *	PULSE DELAY (Δ)	PULSE * WIDTH	OFFSET SWITCH	DP/DELAY SWITCH	NORMAL/COMP SWITCH	RISETIME CONTROL	FALLTIME CONTROL	POLARITY SWITCH	AMPLITUDE * ADJUST
B: RAMP TRIGGER PULSE GENERATOR	EXT/ MANUAL	+(Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	11μ sec.	0.6μ sec.	OFF	DELAY	NORMAL	Minimum (10ns)	Minimum (10ns)	-(Negative	-0.7 volts pk
D: POST-RAMP OFFSET PULSE GENERATOR	EXT/ MANUAL	+(Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	1.5μ sec.	25μ sec.	OFF	DELAY	NORMAL	Minimum (10ns)	Minimum (10ns)	+(Positive	+ 4.0 volts

	TRIGGER POLARITY SW.	TRIGGER * SENSITIVITY	OUTPUT POLARITY SW	STEP INPUT * MAGNITUDE	PRE-RAMP * OFFSET(b) ADJ	AXIS-CROSSING DIRECTOR SW.	DIAL MULTIPLIER	Freq. CPS * (PERIOD)	WAVEFORM	OUTPUT * AMPLITUDE	VCG	50 Ω OUTPUT AMPLITUDE
C: FAST-RISE PULSE GENERATOR	NEG.	As required to get a stable output	POS.									
E: RAMP GENERATOR				220 mv.	-2.0 mv.	PCAC						
A-F: TIME BASE GENERATOR							X10K	25Kc ($T = 40\mu$ sec		Adjust for desired test conditions	Minimum	Maximum

NOTE: 1. Use Ramp Generator # 4
2. Zero-Crossing delay time (d) is 1.53 ns.
3. * Check with Oscilloscope

TABLE 1. ADJUSTMENTS FOR 25 KC OPERATION

NGAC + Output of Variable-V source goes to red binding post.

	OPERATING MODE SW.	TRIGGER SLOPE SW.	THRESHOLD * SENSITIVITY	SLOPE * SENSITIVITY	FREQUENCY *	PULSE DELAY* (Δ)	PULSE * WIDTH	OFFSET SWITCH	DP/DELAY SWITCH	NORMAL/COMP SWITCH	RISETIME CONTROL	FALLTIME CONTROL	POLARITY SWITCH	AMPLITUDE * ADJUST
B: RAMP TRIGGER PULSE GENERATOR	EXT/ MANUAL	-(Negative)	Adjust for stable triggering	Maximum Negative	Not Applicable	110 μsec	0.6 μsec.	OFF	DELAY	NORMAL	Minimum (10ns)	Minimum (10ns)	- (Negative)	-0.7 volts pk.
D: POST-RAMP OFFSET PULSE GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	1.5 μsec	250 μsec	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	-(Negative)	-4.0 volts

	TRIGGER POLARITY SW	TRIGGER * SENSITIVITY	OUTPUT POLARITY SW	STEP INPUT * MAGNITUDE	PRE-RAMP * OFFSET(b) ADJ	AXIS-CROSSING DIRECTION SW.	DIAL MULTIPLIER	Freq. CPS * (PERIOD)	WAVEFORM	(INTER AC) OUTPUT * AMPLITUDE	VCG	50 Ω OUTPUT AMPLITUDE
C: FAST-RISE PULSE GENERATOR	NEG.	As required to get a stable output	NEG.									
E: RAMP GENERATOR				220 mv.	+ 2.0 mv.	NGAC						
A-F: TIME BASE GENERATOR							X1K	2.5Kc T = 400 μs.	∿	Adjust for desired test conditions	Minimum	Maximum

PGAC - + Output of Variable-V source goes to black binding post.

	OPERATING MODE SW.	TRIGGER SLOPE SW.	THRESHOLD * SENSITIVITY	SLOPE * SENSITIVITY	FREQUENCY *	PULSE DELAY* (Δ)	PULSE * WIDTH	OFFSET SWITCH	DP/DELAY SWITCH	NORMAL/COMP SWITCH	RISETIME CONTROL	FALLTIME CONTROL	POLARITY SWITCH	AMPLITUDE * ADJUST
B: RAMP TRIGGER PULSE GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	110 μsec.	0.6 μsec.	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	-(Negative)	-0.7 volts pk
D: POST-RAMP OFFSET PULSE GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	1.5 μsec.	250 μsec.	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	+(Positive)	+4.0 volts

	TRIGGER POLARITY SW.	TRIGGER * SENSITIVITY	OUTPUT POLARITY SW	STEP INPUT * MAGNITUDE	PRE-RAMP * OFFSET(b) ADJ	AXIS-CROSSING DIRECTION SW.	DIAL MULTIPLIER	Freq. CPS * (PERIOD)	WAVEFORM	(INTER AC) OUTPUT * AMPLITUDE	VCG	50 Ω OUTPUT AMPLITUDE
C: FAST-RISE PULSE GENERATOR	NEG.	As required to get a stable output	POS.									
E: RAMP GENERATOR				220 mv.	- 2.0 mV.	PGAC						
A-F: TIME BASE GENERATOR							X1K	2.5 Kc T = 400 μs.	∿	Adjust for desired test conditions	Minimum	Maximum

NOTE:
1. Use RAMP Generator # 3
2. Zero-Crossing delay time (d) is 15.3 ns.
3. * Measure with Oscilloscope

TABLE 2. ADJUSTMENTS FOR 2.5 KC OPERATION

NGAC + Output of Variable-V source goes to red binding post

	OPERATING MODE SW	TRIGGER SLOPE SW	THRESHOLD * SENSITIVITY	SLOPE * SENSITIVITY	FREQUENCY *	PULSE DELAY (Δ)	PULSE * WIDTH	OFFSET SWITCH	DP/DELAY SWITCH	NORMAL/COMP SWITCH	RISETIME CONTROL	FALLTIME CONTROL	POLARITY SWITCH	AMPLITUDE * ADJUST
B: RAMP TRIGGER PULSE GENERATOR	EXT/ MANUAL	- (Negative)	Adjust for stable triggering	Maximum Negative	Not Applicable	1.1 ms.	0.6 μsec	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	-(Negative	-0.7 volts pk
D: POST-RAMP OFFSET PULSE GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	1.5 μsec	2.5 ms.	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	-(Negative	-4.0 volts

	TRIGGER POLARITY SW	TRIGGER * SENSITIVITY	OUTPUT POLARITY SW	STEP INPUT * MAGNITUDE	PRE-RAMP * OFFSET(b) ADJ	AXIS-CROSSING DIRECTION SW.	DIAL MULTIPLIER	Freq. CPS * (PERIOD)	WAVEFORM	(INTER AC) OUTPUT * AMPLITUDE	VCG	50Ω OUTPUT AMPLITUDE
C: FAST-RISE PULSE GENERATOR	NEG.	As required to get a stable output	NEG.									
E: RAMP GENERATOR				220 mv.	+ 2.0 mv.	NGAC						
A-F: TIME BASE GENERATOR							X 100	250 CPS T = 4 ms.		Adjust for desired test conditions	Minimum	Maximum

PGAC + Output of Variable-V source goes to black binding post.

	OPERATING MODE SW	TRIGGER SLOPE SW.	THRESHOLD * SENSITIVITY	SLOPE * SENSITIVITY	FREQUENCY *	PULSE DELAY (Δ)	PULSE * WIDTH	OFFSET SWITCH	DP/DELAY SWITCH	NORMAL/COMP SWITCH	RISETIME CONTROL	FALLTIME CONTROL	POLARITY SWITCH	AMPLITUDE * ADJUST
B: RAMP TRIGGER PULSE GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	1.1 ms.	0.6 μsec	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	-(Negative	-0.7 volts pk
D: POST-RAMP OFFSET PULSE GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	1.5 μsec.	2.5 ms.	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	+(Positive	-4.0 volts

	TRIGGER POLARITY SW	TRIGGER * SENSITIVITY	OUTPUT POLARITY SW	STEP INPUT * MAGNITUDE	PRE-RAMP * OFFSET(b) ADJ	AXIS-CROSSING DIRECTION SW.	DIAL MULTIPLIER	Freq. CPS * (PERIOD)	WAVEFORM	(INTER AC) OUTPUT * AMPLITUDE	VCG	50Ω OUTPUT AMPLITUDE
C: FAST-RISE PULSE GENERATOR	NEG.	As required to get a stable output	POS.									
E: RAMP GENERATOR				220 mv.	-2.0 mv.	PGAC						
A-F: TIME BASE GENERATOR							X 100	250 CPS T = 4 ms		Adjust for desired test conditions	Minimum	Maximum

NOTE: 1. Use RAMP Generator # 2
2. Zero-Crossing delay time (d) is 153 ns
3. * Check with Oscilloscope

TABLE 3. ADJUSTMENTS FOR 250 CPS OPERATION

NGAC + Output of Variable-V source goes to red binding post

	OPERATING MODE SW.	TRIGGER SLOPE SW.	THRESHOLD * SENSITIVITY	SLOPE * SENSITIVITY	FREQUENCY *	PULSE DELAY* (Δ)	PULSE * WIDTH	OFFSET SWITCH	DP/DELAY SWITCH	NORMAL/COMP SWITCH	RISETIME CONTROL	FALLTIME CONTROL	POLARITY SWITCH	AMPLITUDE * ADJUST
B: RAMP TRIGGER PULSE GENERATOR	EXT/ MANUAL	- (Negative)	Adjust for stable triggering	Maximum Negative	Not Applicable	11.0 ms.	0.6μsec	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	-(Negative)	-0.7 volts pk
D: POST-RAMP OFFSET PULSE GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	1.5μs	25 ms	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	-(Negative)	-4.0 volts

	TRIGGER POLARITY	TRIGGER * SENSITIVITY	OUTPUT POLARITY SW.	STEP INPUT * MAGNITUDE	PRE-RAMP OFFSET(b) ADJ	AXIS-CROSSING DIRECTION	DIAL MULTIPLIER	Freq. CPS* (PERIOD)	WAVEFORM	(INTER AC) OUTPUT AMPLITUDE *	VCG	50Ω OUTPUT AMPLITUDE
C: FAST-RISE PULSE GENERATOR	NEG.	As required to get a stable ouput	NEG.									
E: RAMP GENERATOR				220 mv.	+ 2.0 mv.	NGAC						
A-F: TIME BASE GENERATOR							X 1000	25 CPS T = 40 ms		Adjust for desired test conditions	Minimum	Maximum

PGAC + Output of Variable-V source goes to black binding post

	OPERATING MODE SW	TRIGGER SLOPE SW.	THRESHOLD * SENSITIVITY	SLOPE * SENSITIVITY	FREQUENCY *	PULSE DELAY (Δ)	PULSE * WIDTH	OFFSET SWITCH	DP/DELAY SWITCH	NORMAL/COMP SWITCH	RISETIME CONTROL	FALLTIME CONTROL	POLARITY SWITCH	AMPLITUDE * ADJUST
B: RAMP TRIGGER PULSE GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	11.0 ms	0.6μsec	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	-(Negative	-0.7 volts pk
D: POST-RAMP OFFSET PULSE GENERATOR	EXT/ MANUAL	+ (Positive)	Adjust for stable triggering	Maximum Positive	Not Applicable	1.5μsec	25 ms	OFF	DELAY	NORMAL	Minimum (10ns.)	Minimum (10ns.)	+(Positive	+4.0 volts

	TRIGGER POLARITY SW	TRIGGER * SENSITIVITY	OUTPUT POLARITY SW	STEP INPUT * MAGNITUDE	PRE-RAMP OFFSET(b) ADJ	AXIS CROSSING DIRECTION	DIAL MULTIPLIER	Freq. CPS * (PERIOD)	WAVEFORM	(INTER AC) OUTPUT AMPLITUDE *	VCG	50Ω OUTPUT AMPLITUDE
C: FAST-RISE PULSE GENERATOR	POS.	As required to get a stable output	POS.									
E: RAMP GENERATOR				220 mv.	- 2.0 mv.	PGAC						
A-F: TIME BASE GENERATOR							X 1000	25 CPS T = 40 ms		Adjust for desired test conditions	Minimum	Maximum

NOTE:
1. Use RAMP Generator # 1
2. Zero-Crossing delay time (d) is 1530 ns = 1.53μsec
3. * Measure with Oscilloscope

TABLE 4. ADJUSTMENTS FOR 25 CPS OPERATION